Renewable Energy Technology Opportunities: Responding to Global Energy Challenges

Presented at Clean-Tech Investors Summit

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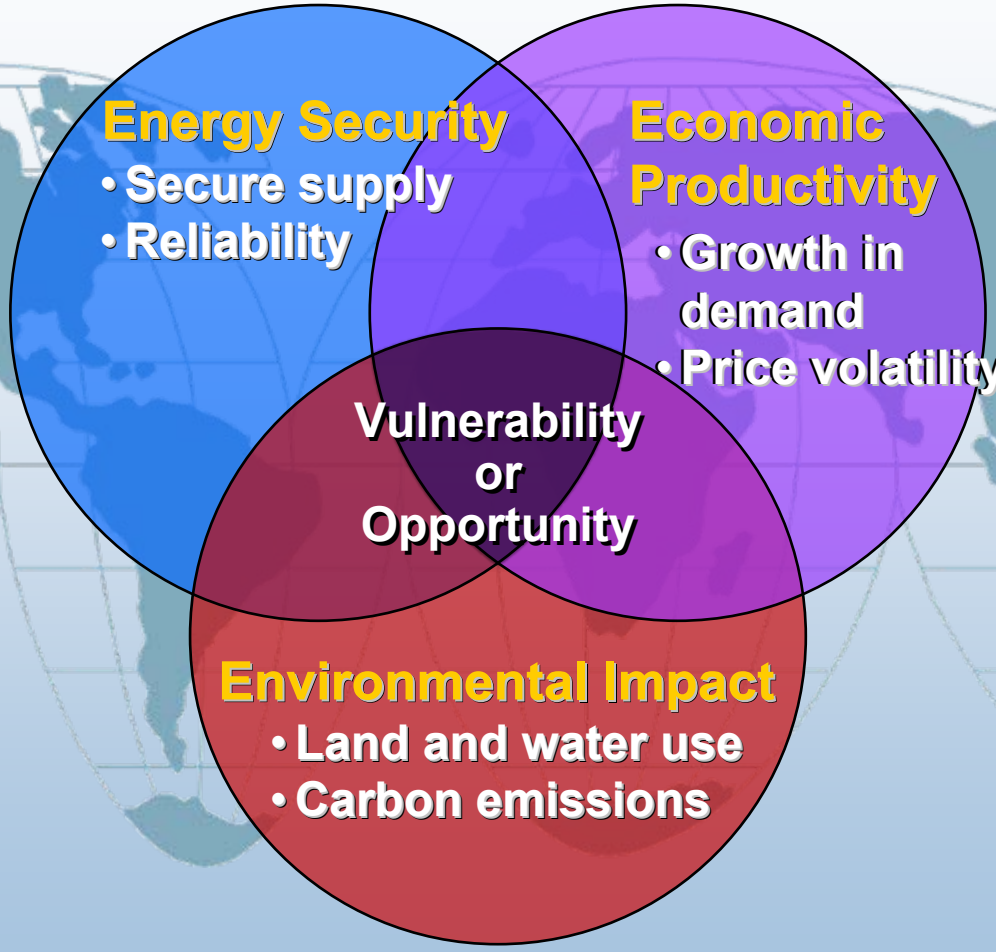
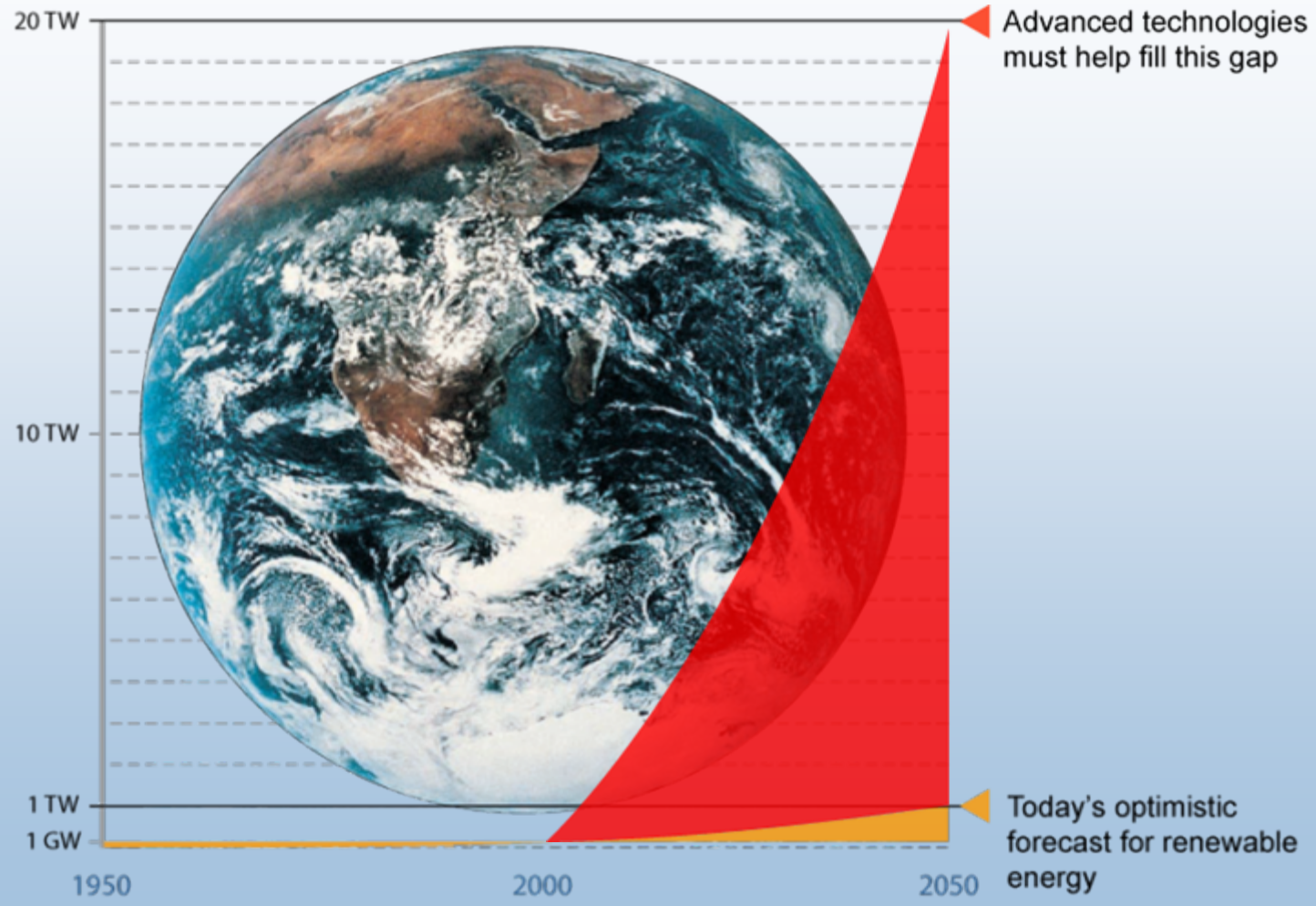
Energy Solutions Are Enormously Challenging



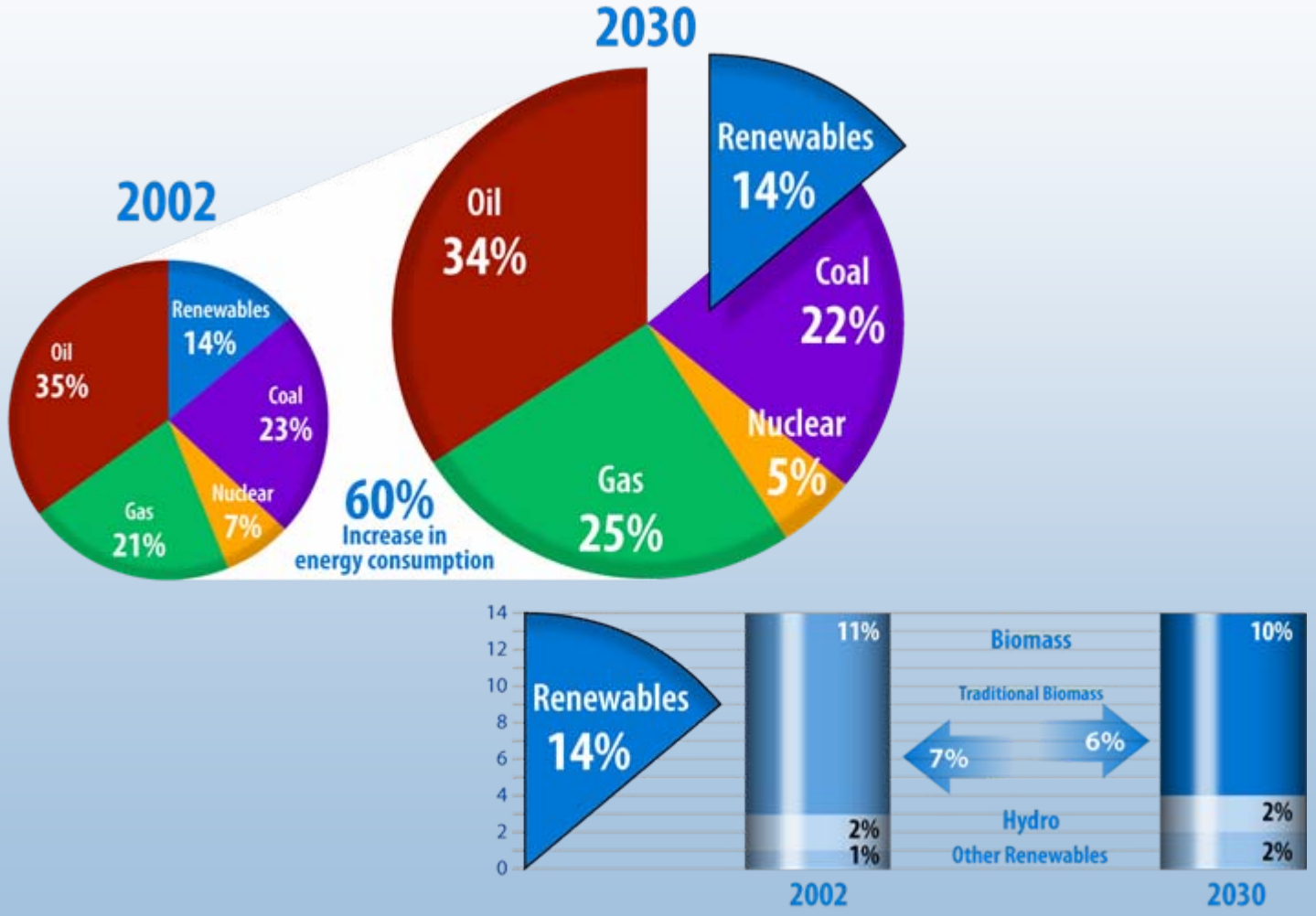
Must address all three imperatives

How Big is the Challenge?



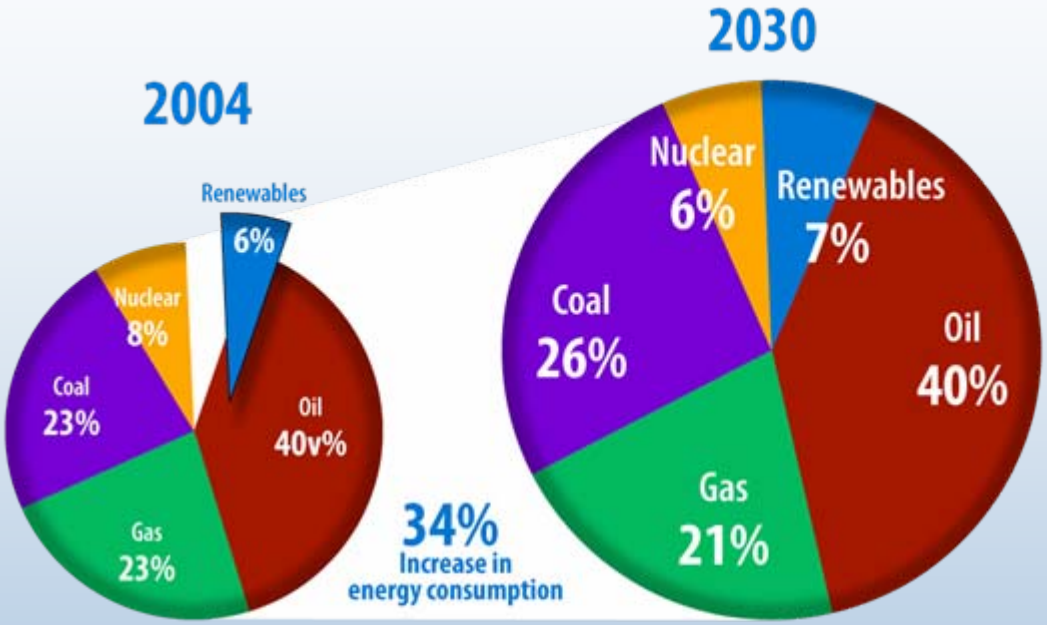
Source: Arvizu, NREL

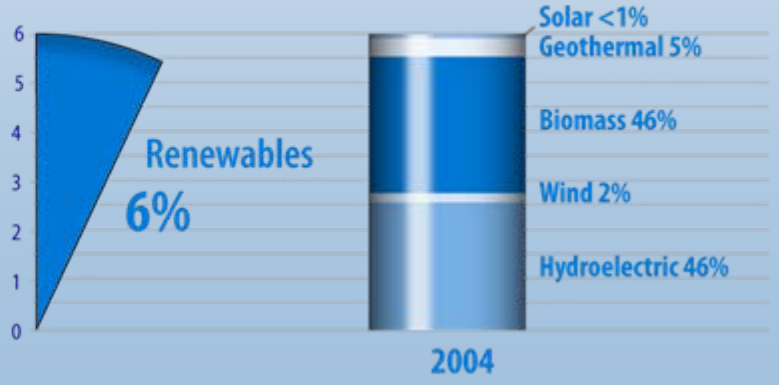
World Energy Supply and the Role of Renewable Energy



Source: OECD/IEA, 2004

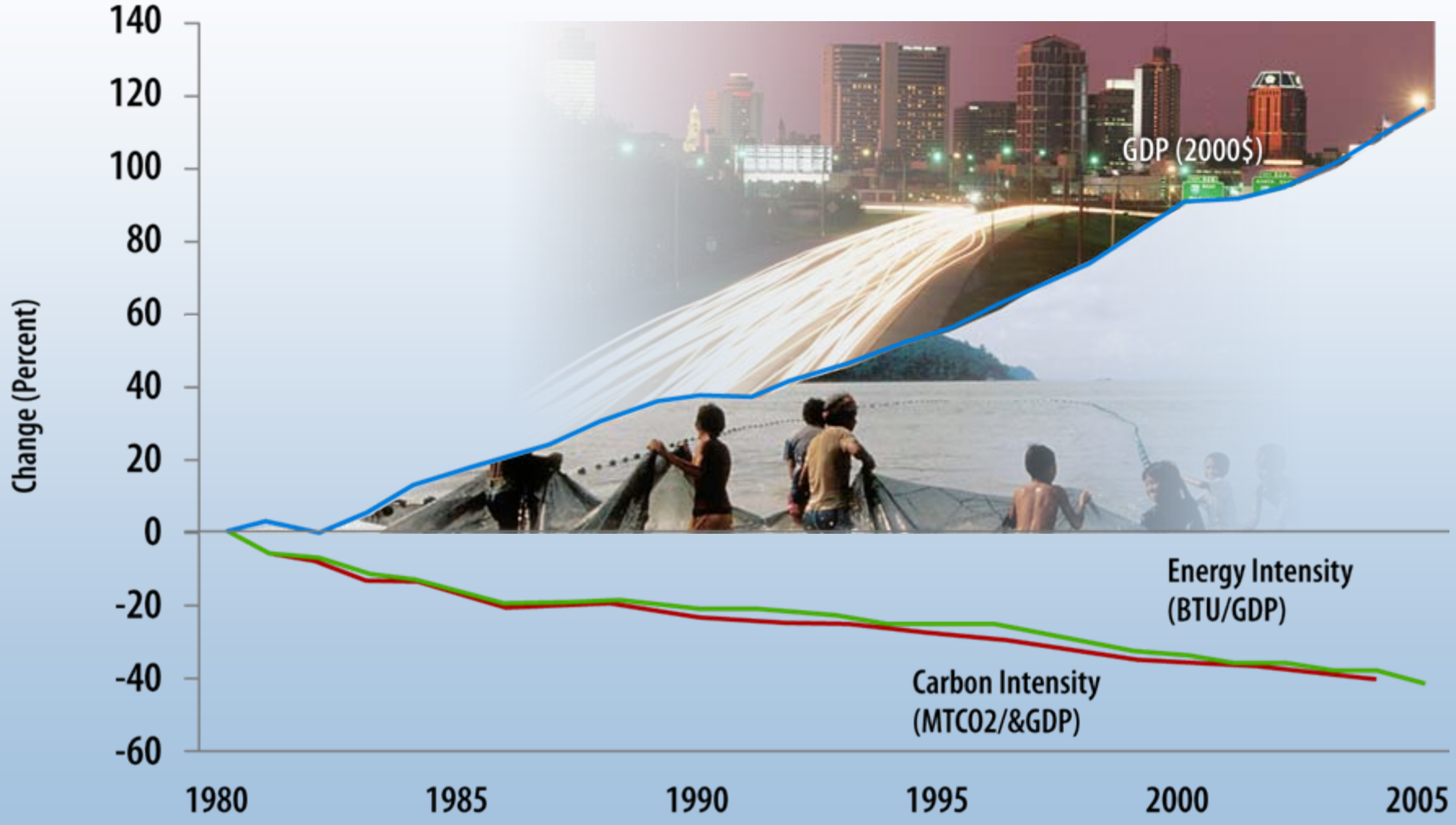
U.S. Energy Consumption and the Role of Renewable Energy





Source: Energy Information Administration, *Annual Energy Outlook 2006,* Table D4

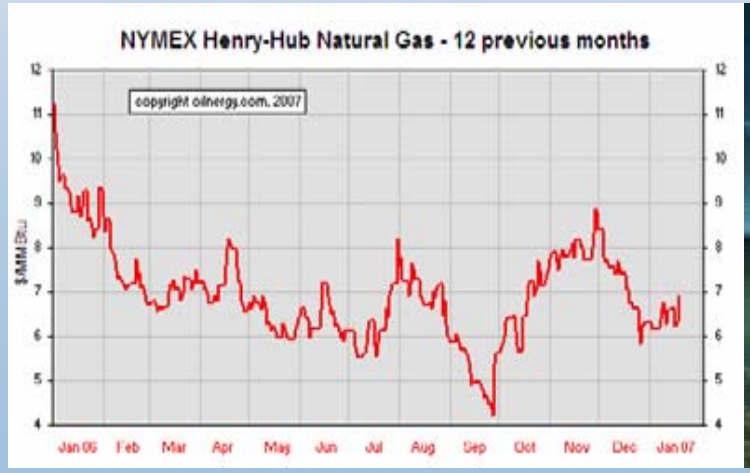
Carbon and Energy Intensity



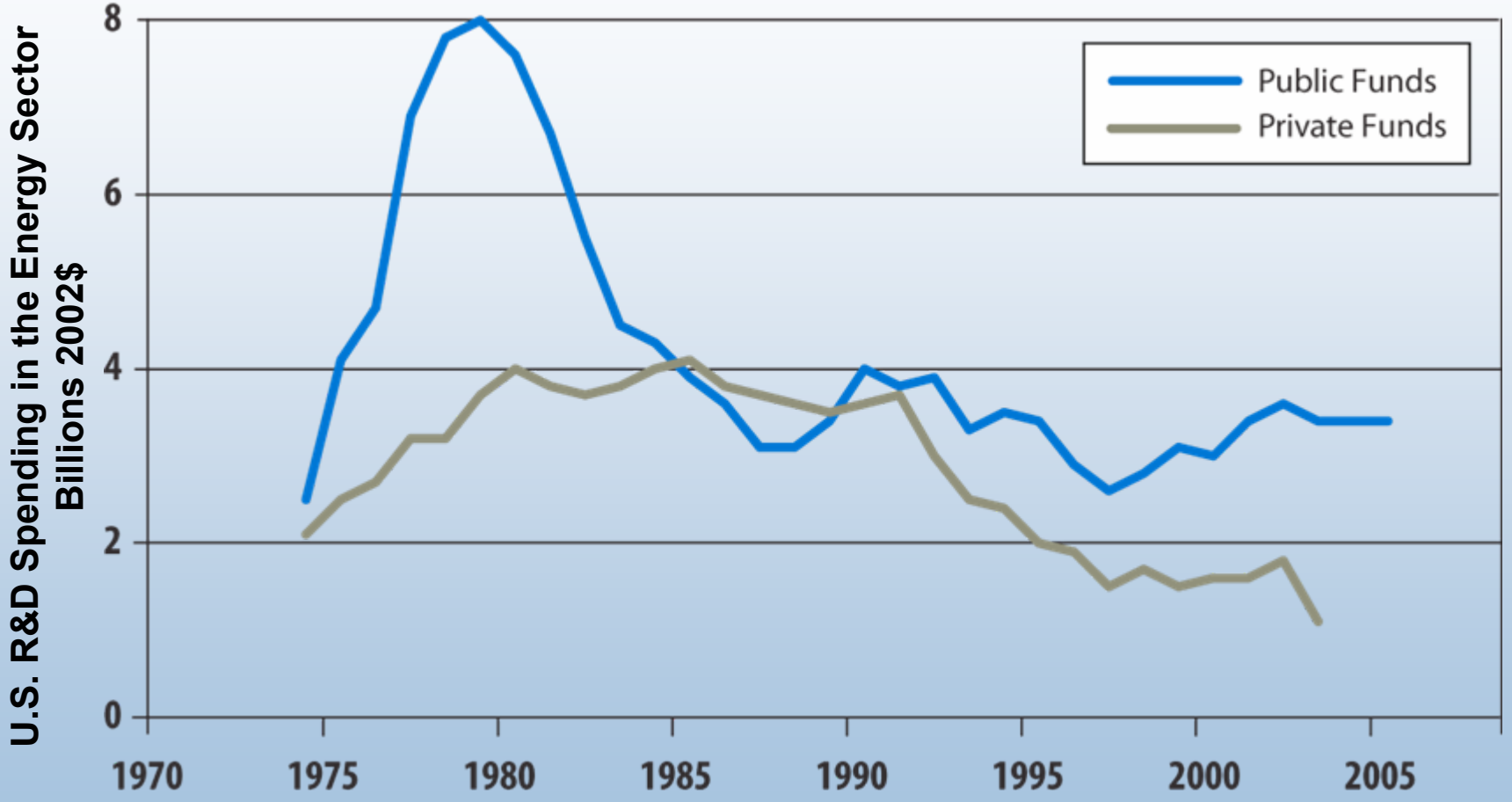
Source: Energy Information Administration, “Annual Energy Review 2005”, DOE/EIA-0384(2005), Table 1.5

Thinking Differently…
Account for Externalities

- Today's energy marketplace does not appropriately "value" certain public objectives or social goods, instead we have:
  - Price volatility
  - Serious environmental impacts
  - Underinvestment in energy innovation

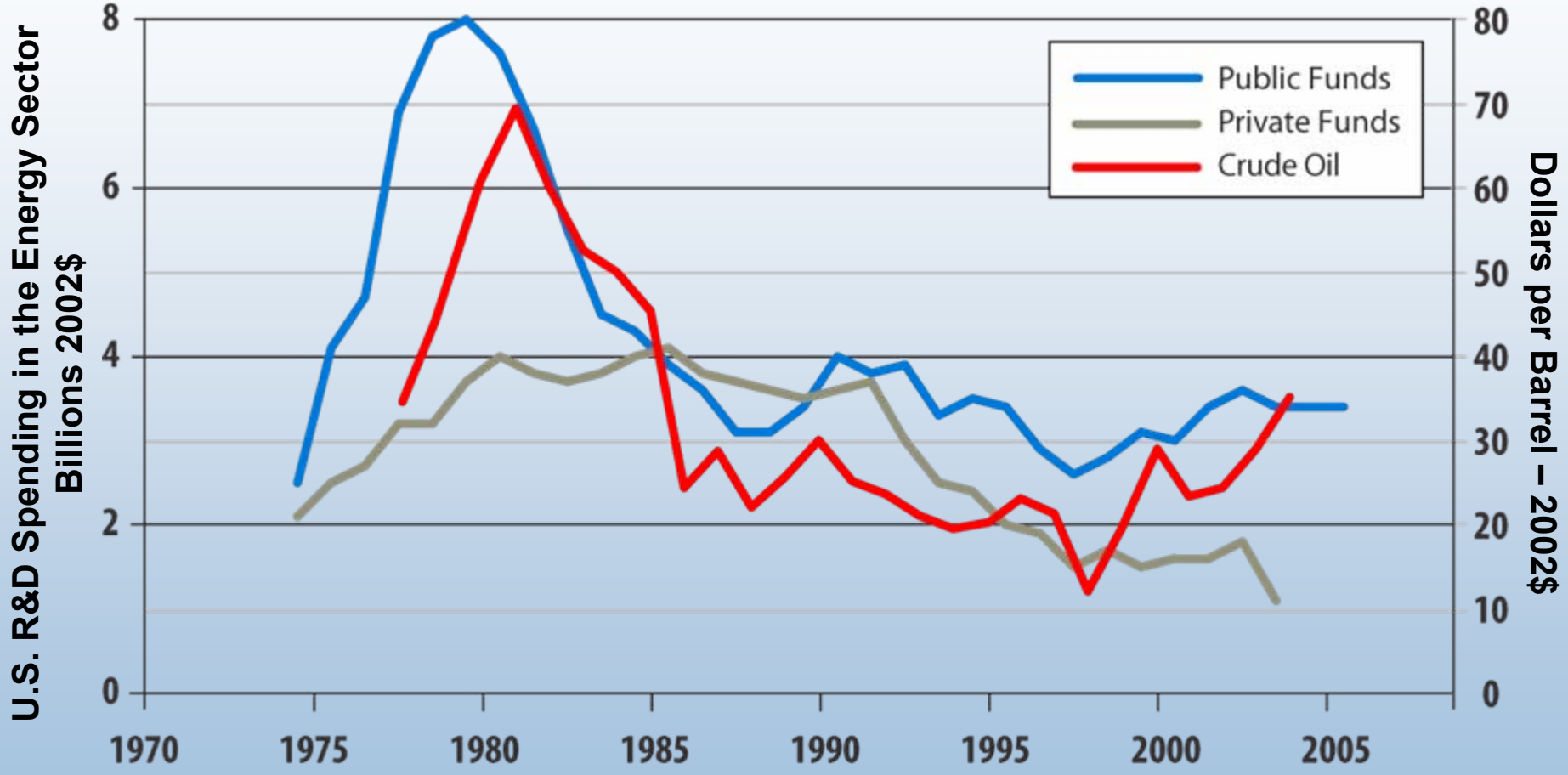


Declining Energy R&D Investments…



Source: Daniel Kammen, Gregory Nemet *Reversing the Incredible, Shrinking Energy R&D Budget* http://rael.berkeley.edu/files/2005/Kammen-Nemet-ShrinkingRD-2005.pdf
Table 10.3, Edition 25, *Transportation Energy Data Book* http://cta.ornl.gov/data/chapter10.shtml

Declining Energy R&D Investments… Reflect World Oil Price Movement



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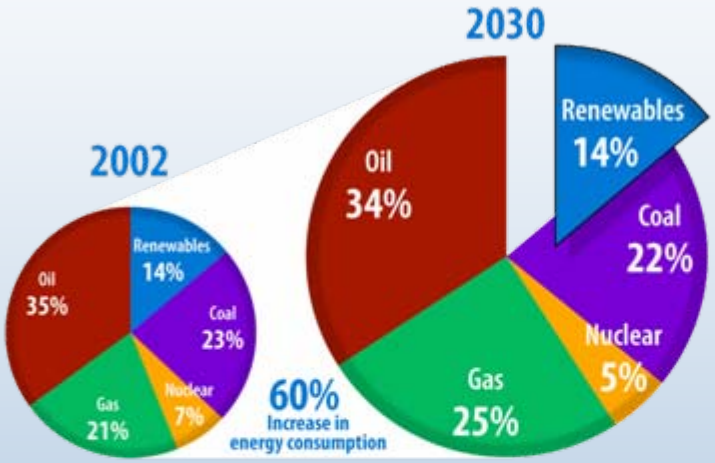
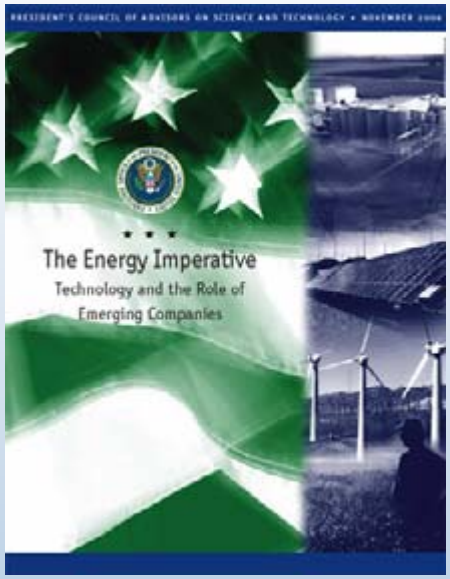
World Energy Supply and the Role of Renewable Energy





"…in the foreseeable future, the share of non-hydroelectric renewable electricity generation in the U.S. could grow to 10% or more by 2030 and to over 20% by midcentury."

PCAST Nov 2006

"Yes if" … not… "no because."

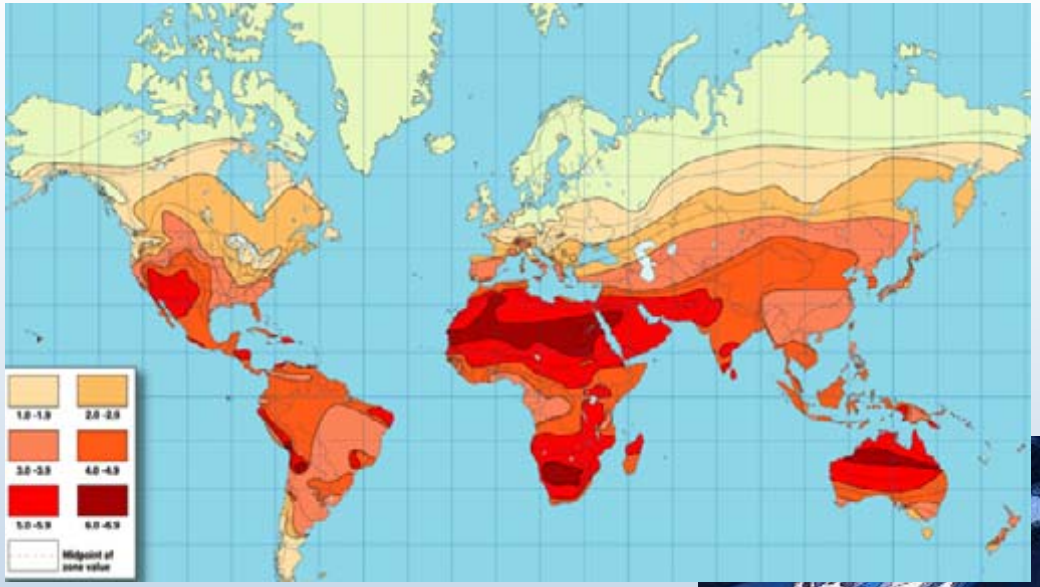
– Newt Gingrich

Source: OECD/IEA, 2004

Technology-Based Solutions:
There is no single or simple answer

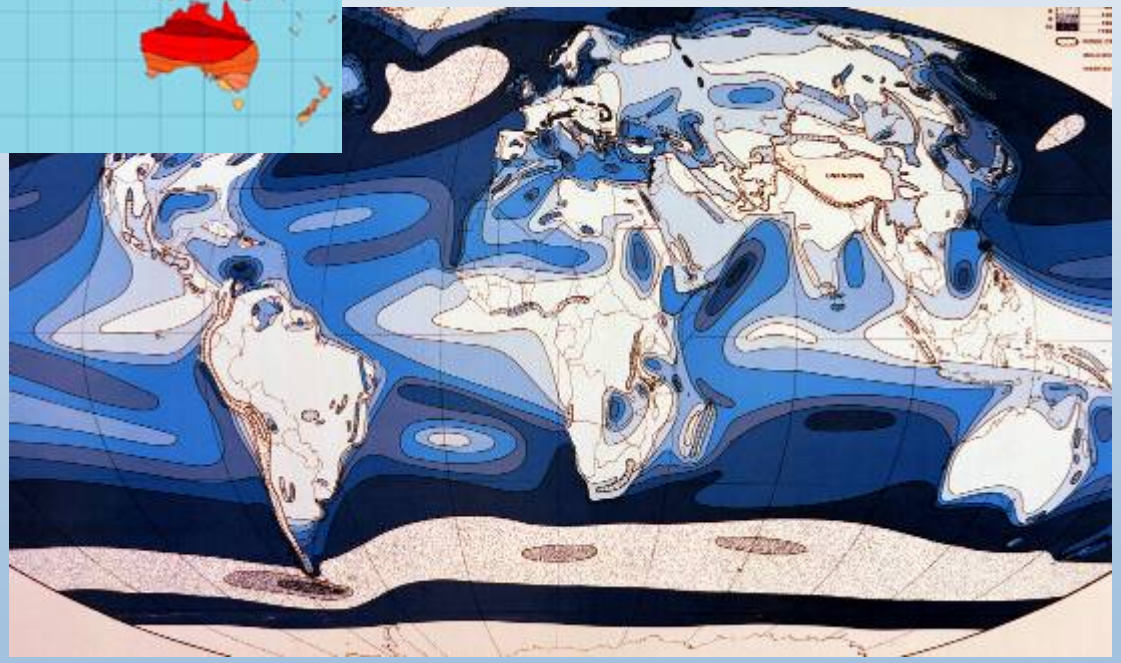
- Energy efficiency
- Renewable energy
- Nonpolluting transportation fuels
- Separation and sequestration of CO_2
- Next generation nuclear energy technologies
- Transition to distributed energy systems coupled with pollution-free energy carriers

Global Resources are Plentiful



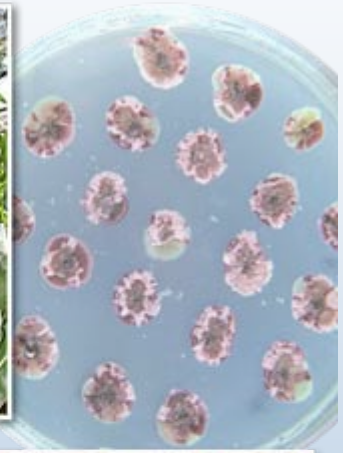
Solar

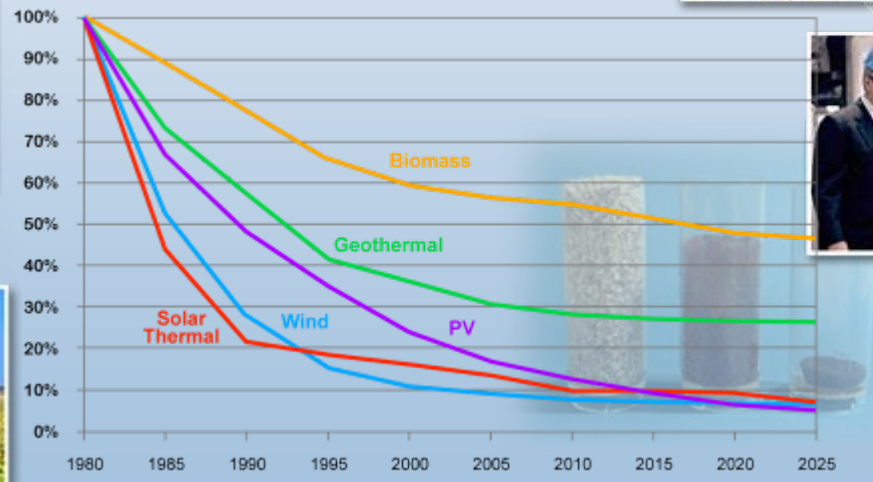
Wind



Source: http://howto.altenergystore.com/Reference-Materials/Solar-Insolation-Map-World/a43/
Pacific Northwest National Laboratory

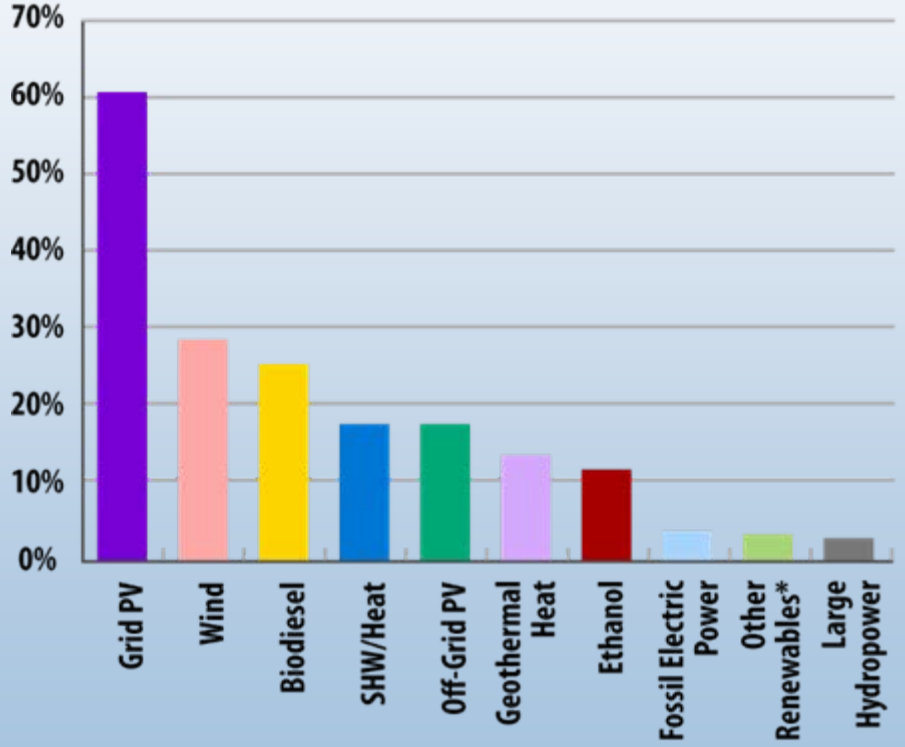
Impressive Cost Reductions



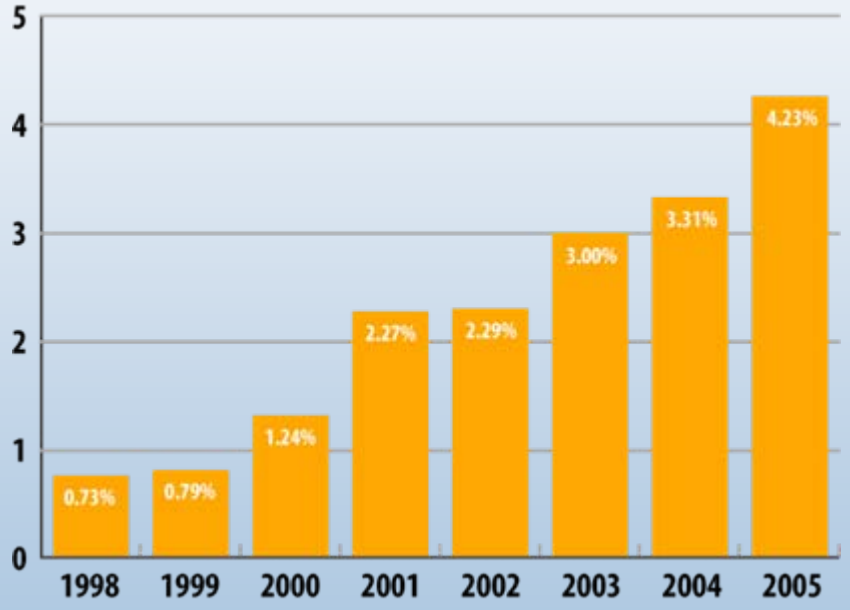


Investing in the Future

Global Renewable Energy Annual Growth Rates 2000-2004



Energy-Tech Investments Percent of Total U.S. Venture Capital



Sources:
Renewables 2005 Global Status Report, REN21
Clean Energy Trends 2006, Nth Power LLC

Getting to “Significance” Involves…

Source: NREL

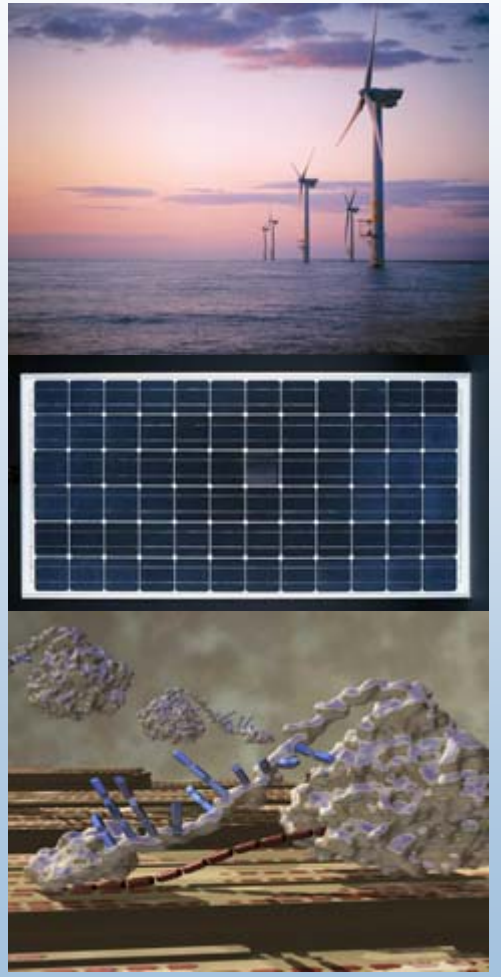
Consistent Policies are Required for Long-Term Market Growth

- National goals
  - Biofuels: 30% of gasoline by 2030
  - Wind: 20% of electricity generation by 2030
  - Solar: Be market competitive by 2015 for Solar PV
- Infrastructure investments required to meet these goals, for example:
  - Biofuels: 30x30 analysis estimated infrastructure cost between $8.5 and $28.5B over 23 years

Aging Energy Infrastructure

Technology Innovation Challenges

- Wind
  - Next generation wind turbines
    - Improve energy capture by 30%
    - Decrease capital costs by 25%
- Solar photovoltaics
  - Improved performance through
    - process improvements
    - better materials
    - concentration
  - Harnessing nanostructures & new quantum effects
- Biofuels
  - Next generation biofuels
    - New feedstocks
    - Improved energy crops
    - Integrated biorefineries



Wind

Today's Status in U.S.

- 11,603 MW installed at end of 2006
- Cost 6-9¢/kWh at good wind sites*

DOE Cost Goals

- 3.6¢/kWh, onshore at low wind sites by 2012
- 7¢/kWh, offshore in shallow water by 2014

Long Term Potential

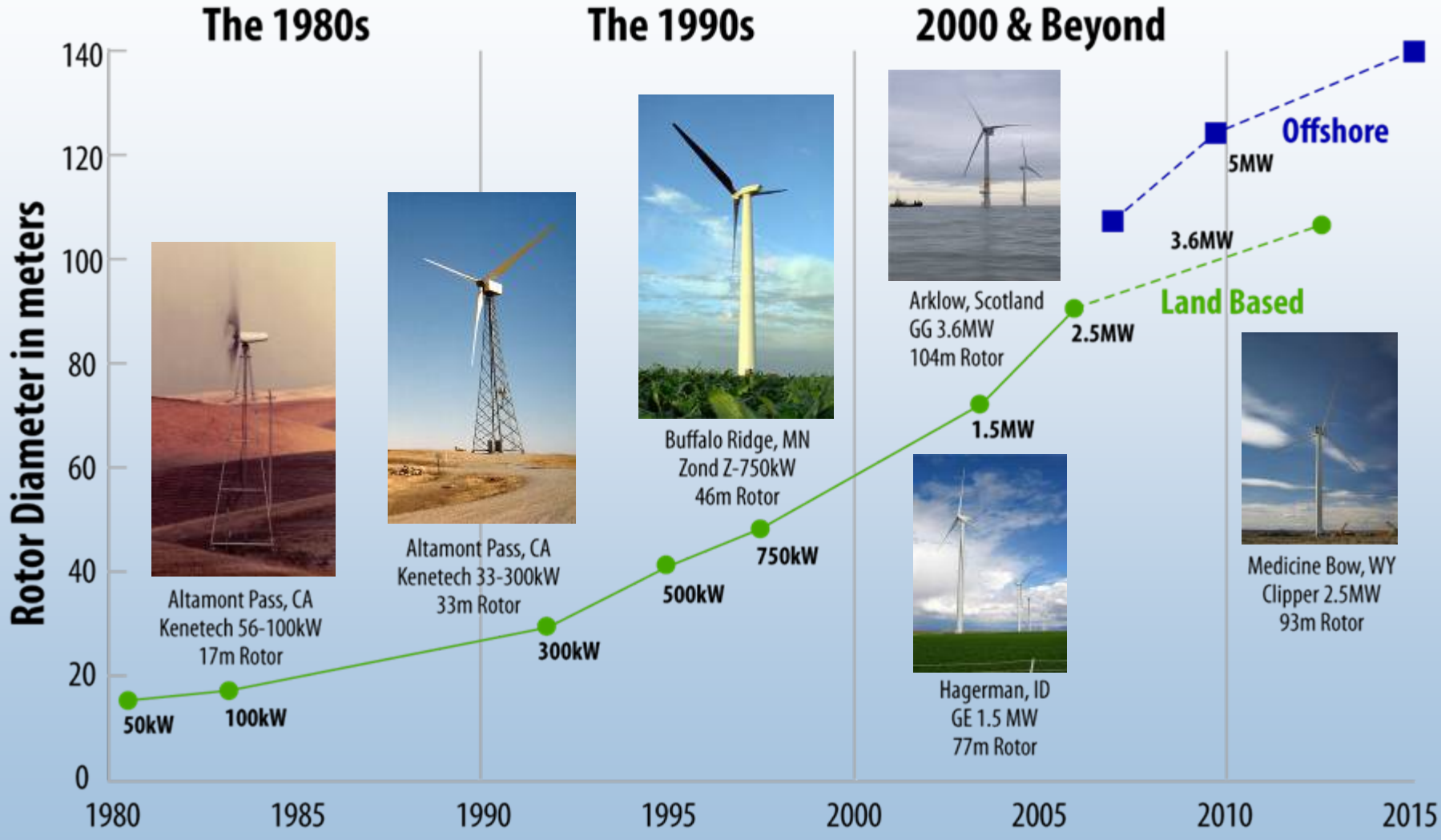
- 20% of the nation's electricity supply

NREL Research Thrusts

- Improved performance and reliability
- Distributed wind technology
- Advanced rotor development
- Utility grid integration

* With no Production Tax Credit
Updated January 23, 2007
Source: U.S. Department of Energy, American Wind Energy Association

Evolution of U.S. Commercial Wind Energy



Solar

Photovoltaics and Concentrating Solar Power

Status in U.S.

PV
- 526 MW
- Cost 18-23¢/kWh

CSP
- 355 MW
- Cost 12¢/kWh

Potential:

PV
- 11-18¢/kWh by 2010
- 5-10 ¢/kWh by 2015

CSP
8.5 ¢/kWh by 2010
6 ¢/kWh by 2015

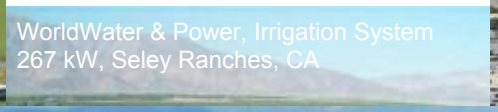
Source: U.S. Department of Energy, IEA
Updated November 8, 2006

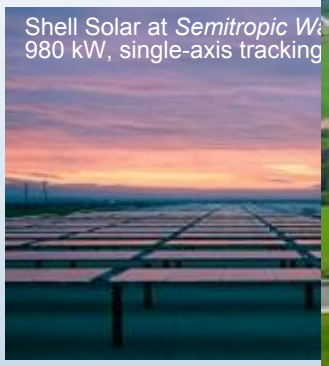
NREL Research Thrusts:

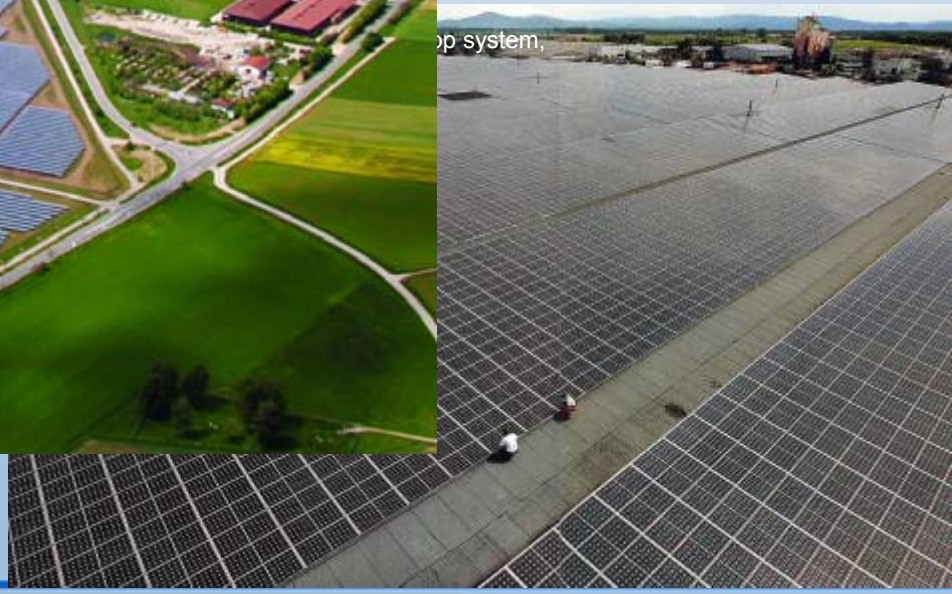
PV
- Partnering with industry
- Higher efficiency devices
- New nanomaterials applications
- Advanced manufacturing techniques

CSP
- Next generation solar collectors
- High performance storage

…toward our destination







Biofuels

Current Biofuels status

- Biodiesel – 91 million gallons[1] (2005)
- Corn ethanol (Nov. 2006)
  - 106 commercial plants[2]
  - 5.1 billion gallon/yr. capacity[2]
  - 3rd Q 2006 rack price highly variable $3.50 – 5.50/gallon of gasoline equivalent (gge)[3]
- Cellulosic ethanol
  - Projected commercial cost ~$3.50/gge

Key DOE Goals

- 2012 goal: cellulosic ethanol ~$1.62/gge
- 2030 goal: 60 billion gal ethanol (30% of 2004 gasoline)

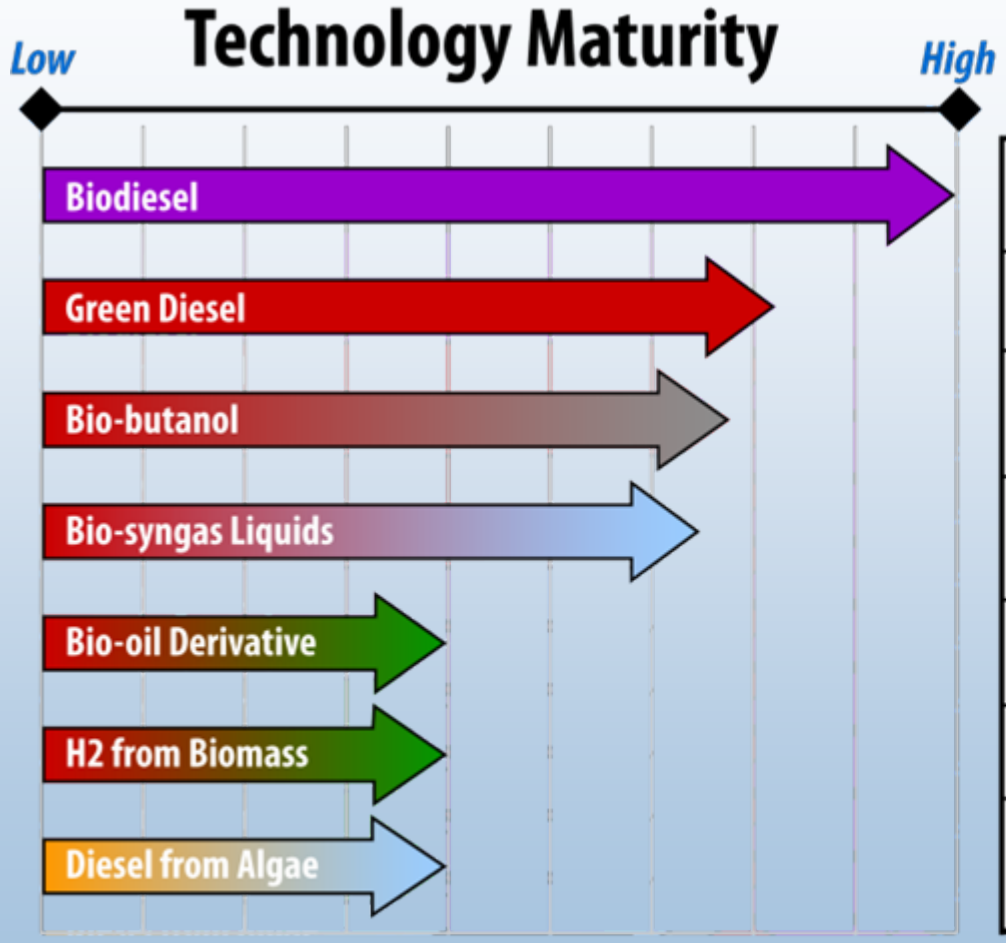
NREL Research Thrusts

- The biorefinery and cellulosic ethanol
- Solutions to under-utilized waste residues
- Energy crops

Updated November 10, 2006

Sources: 1- National Biodiesel Board, 2 - Renewable Fuels Association, 3 – American Coalition for Ethanol, all other information based on DOE and USDA sources

Biofuels R&D



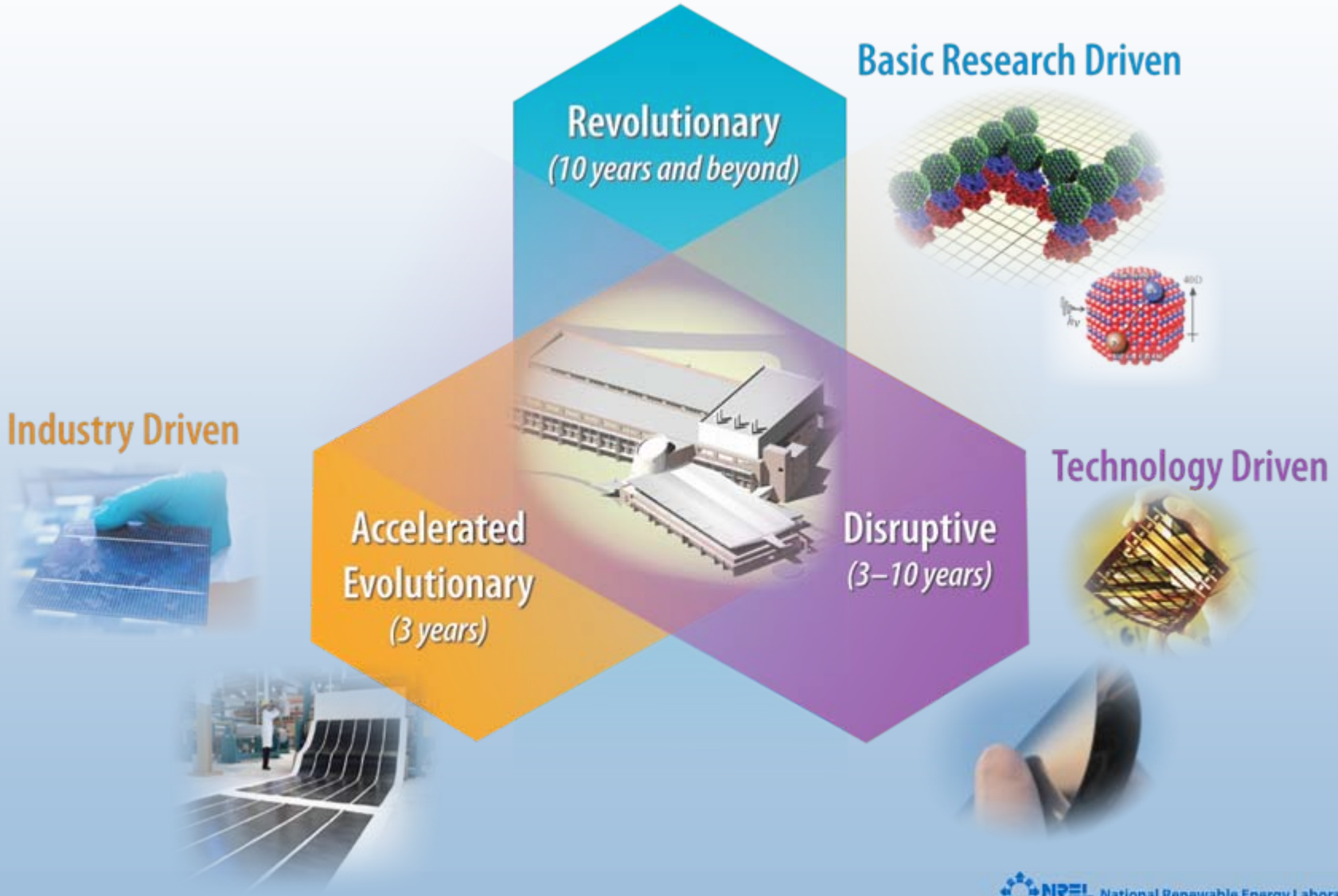
Key Drivers	Value Added
New market for excess oils, fats, and greases.	Petroleum compatible and biodegradable.
Lower cost and higher product quality than FAME.	Utilize existing assets. High quality jet fuel or diesel.
New market for grain and agriculture products. Large supply of lignocellulose.	Better gasoline blending properties than ethanol.
Integration of biomass with Coal, Coke, Shale, or Heavy Oils.	High quality jet fuel or diesel. Reduced criteria for sequestration, and economy of scale (in combination with fossil).
Technical fit with woody biomass and liquid bio-crude.	Potential to integrate into existing large scale refinery and pipeline infrastructure.
Potential transportation fuel from any fuel/power source.	Ideal feed for fuel cells, and lowest tail pipe emissions.
Lg. source of biomass on non-arable land, and capture of CO^2.	High quality jet fuel or diesel yield per acre, with both off-shore and on-shore potential.

Renewable Fuels & Low GHG Emissions

Organizations Leading the R&D

- Grain/Agriculture
- Petroleum
- Coal
- Forestry
- Chemical
- Academia & Startups

Technology Investment Pathways



Promise of renewable energy is profound and can be realized if we…

- Aggressively seek a global sustainable energy economy
- Accelerate investment in technology innovation
- Acknowledge and mitigate the carbon challenge with the necessary policies

It is a matter of national will and leadership